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The Early History of the Cornell Mathematics Department: A Case Study in the Emergence of the American Mathematical Research Community

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In this paper I describe the early history of the Cornell University mathematics department in the historical context of the late 19th century. In particular, I show that it is a case study of the emergence of the American mathematical community. © 1998 Academic Press

En este ensayo, describo la premera historia de departamento de matematica de Cornell Universitad en el contexto de Siglo XIX. En particular, demonstro que este departamento es un ejemplo do lar emergencia de communidad matematica de Estados Unidos. © 1998 Academic Press

In dieser Arbeit beschreibe ich die Frühgeschichte des Mathematics Department der Cornell University während des ausgehenden neunzehnten Jahrhunderts. Ich zeige insbesondere, daβ diese Geschichte als Fallstudie für die Entstehung der amerikanischen Mathematikergemeinschaft angesehen werden kann. © 1998 Academic Press

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1. INTRODUCTION

In their significant works, Parshall and Rowe [45; 46], Fenster and Parshall [28; 29], and Parshall [44] clearly make the case for the emergence of the American mathematical research community in the last quarter of the 19th century. Parshall puts it this way: ‘‘In the last quarter of the 19th century, American mathematics underwent a series of dramatic changes that propelled it onto the international scene’’ [44, 7]. She credits the ‘‘opening of the Johns Hopkins University in Baltimore with its explicitly articulated purpose of training students at an advanced, graduate level’’ [44, 7] as the beginning of this period of change. But with the departure of James Joseph Sylvester (1814–1897), the English transplant algebraist, from Baltimore for England in 1883, the American mathematical scene had lost a leader for change. Almost exclusively, America looked to Europe for guidance. Many American students of promise thus went to Europe for their doctorates or for post-doctoral work in the 1880s and 1890s. When this generation of European-trained mathematicians came back and took the lead in their institutions, a viable mathematical research community emerged. In this paper, I will show that the early history of the Cornell mathematics department represents a case study of this emergence. In fact, in the first decades of the 20th century, Cornell was among the leaders in effecting these developmental changes.

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2. THE BIRTH OF AN AMERICAN UNIVERSITY

Through the extensive efforts of historian Andrew Dickson White (1832–1918), and telegraph magnate Ezra Cornell (1807–1874), "the first American University" [12, 334] was born in 1868. Both men came into their joint effort through vastly different sets of circumstances.

Ezra Cornell was born in Westchester County, New York (today the Bronx section of New York City), the son of Quaker parents of modest means. When he was young, his family moved to a farm in DeRuyter, New York, in the western part of the state, and he was brought up as a potter and a carpenter. With little formal schooling, he left home at the age of 19 to seek his own fortune. By 1828, he had been drawn to Ithaca (on the south banks of Cayuga Lake) to work as a carpenter during the building boom there. Over the next decade, he earned a reputation as an "industrious small-town artisan" [11, 12]. When recession hit the economy of the United States in 1837, however, the economic slowdown caused the cancellation of the project for connecting Cayuga Lake with Lake Ontario (and hence Ithaca's hopes of being connected to a wider transportation network were dashed). Hard times also naturally hit the building boom in Ithaca, and by January 1, 1839, Cornell found himself out of a job. After a number of failed ventures, he became involved in the experimental telegraph line of Samuel F. B. Morse and supervised the laying of the first telegraph line in America between Baltimore and Washington, DC in 1843. As the telegraph spread across the country, Cornell rode the ups and downs of the new industry. In 1857, he helped form the Western Union Telegraph Company, which soon led the industry. That same year, tired of the day-to-day operations of the telegraph business, Cornell returned to a simpler life in Ithaca. He bought and moved his family onto the 300-acre DeWitt farm on the hill between the two deep gorges overlooking Cayuga Lake and Ithaca. There, he poured his energy into creating a model farm (now the site of Cornell University), organized a local agricultural club, and wrote about agriculture for the town paper. In 1862, he traveled abroad as an official delegate of the New York State Agricultural Society and learned of farming practices in England and France. When he was elected to the New York State Senate in 1863, he quite naturally became the chair of its Committee on Agriculture. It is in this setting that he first met Andrew White.

Andrew Dickson White was born to well-to-do parents in Homer, New York (some 30 miles south of Syracuse, New York). His family eventually moved to Syracuse and there made their mark as "dealers in money, well served in spacious houses" [11, 30]. White never knew the feeling of want. He had good schooling as a boy and wished to go to college at either Harvard or Yale. His father, however, forced him to go to Geneva (today Hobart and William Smith) College in Geneva, New York, to receive an Episcopalian education. White tolerated only one year of "the regime of the religious-oriented college" [50, 68] before moving on to Yale, where he graduated in 1853. Although he enjoyed his years in New Haven, White was unsatisfied with the methods of instruction in higher education that prevailed there. As he put it, "[t]here was too much reciting by rote and too little real intercourse between teacher and taught'' [11, 33]. It was this colonial view of American higher education ''whose watchword was the much repeated phrase 'mental disipline' '' that White so much opposed [53, 21].

After graduating from Yale, White traveled to Europe, studying in Paris, serving as French interpreter to the American Minister to Russia, and finally entering the University of Berlin, where they ''were remaking the concept of historical study'' [11, 34]. He returned to America in 1856 and accepted a professorship in history at the University of Michigan the following year. This position freed him from the conventional form of higher education in America that he so disliked.

Michigan's President, Henry Philip Tappan (1805–1881), had consciously modeled his university on the German institutions of higher education [53, 10], and White was influenced by Tappan's interpretation: a nonsectarian institution operating successfully and giving students curricular freedoms absent from most other colleges of the day. It was during his time at Michigan that White first articulated his own vision of the ideal university. In an 1862 proposal to Gerrit Smith, a wealthy abolitionist and reformer from Peterboro (near Syracuse), White argued that to found a university it was necessary

> First to secure a place where the most highly prized instruction may be afforded to all—regardless of sex or color. Second, to turn the current of mercantile morality which has so long swept through this land.
>
> Thirdly, to temper and restrain the current of military passion which is to sweep through the land hereafter.
>
> Fourthly, to afford an asylum for Science—where truth shall be sought for truth's sake, where it shall not be the main purpose of the Faculty to stretch or cut science exactly to fit ''Revealed Religion.''
>
> Fifthly, to afford a center and a school for a new Literature—not graceful and indifferent to wrong but earnest-nerved and armed to battle for the right.
>
> Sixthly, to give a chance for instruction in moral philosophy, history and political economy unwarped to suit present abuses in politics and religion.
>
> Seventhly, to secure the rudiments, at least, of a legal training in which Legality shall not crush Humanity.
>
> Eighthly, to modify the existing plan of education in matters of detail where it is in vain to hope improvement from the existing universities.
>
> Ninthly, to afford a nucleus around which liberally-minded men of learning—men scattered throughout the land, comparatively purposeless and powerless,—could cluster, making this institution a center from which ideas and men shall go forth to bless the nation during ages. [9, 156–157]

Smith declined to underwrite a university along the lines detailed by White, but these points encompass many of the ideas that subsequently guided the founding of Cornell University. They also expose ''the mind of Andrew D. White–his fervor, his broad humanitarianism (with special notice of Negroes and women), his hostility to organized dogmatic churches, his concept of literature and history as moral and social forces'' [11, 42].

White remained at Michigan for only five years, leaving in 1862 to try to cure a severe case of dyspepsia. He traveled abroad and even tried to enlist the British in the Union cause during the Civil War. On his return to the United States, he settled back in Syracuse and was quickly nominated as a Republican candidate to the New York State Senate. He won the election in 1863 and became chair of the committee in charge of educational matters, the so-called Committee on Literature [11, 42].

Thus in January 1864, two freshmen State Senators, Ezra Cornell and Andrew White, met in Albany for the first time. Cornell's controlling stock in Western Union had made him a wealthy man; his yearly income in 1860 had only been $15,000, but it had risen to $140,000 by 1864 [9, 61]. As a Senator, he aimed ‘‘to spend [his] large income to do the greatest good to those who [were] properly dependent on [him], to the poor and to posterity'' [9, 62]. To this end, he lobbied for a public library for Ithaca; the incorporation bill had to go through White's Committee on Literature. White was so impressed by Cornell's act of philanthropy that he wrote, ‘‘On reading this bill I was struck, not merely by his gift of one hundred thousand dollars to his townsmen, but even more by a certain breadth and largeness in his way of making it.... This breadth of mind, even more than his munificence, drew me to him'' [11, 59].

In fact, White and Cornell soon worked together to secure recently appropriated Federal land grant resources to move the Ovid Agricultural College to Ithaca.[1] Using these funds together with Cornell's gift of his Dewitt farm and $500,000, White was finally able to create the ‘‘great university'' of his dream.

On February 7, 1865, White introduced a bill before the New York State Senate to establish Cornell University as the state's land grant institution. As White phrased it, the school aimed at ‘‘the cultivation of the arts and sciences and of literature, and the instruction in agriculture, the mechanic arts and military tactics, and in all knowledge'' [9, 162]. The next three months witnessed much political warfare, but on April 27, 1865, Governor Reuben E. Fenton (1819–1885) signed the bill into law and so formalized the conception of Cornell University. It very quickly became obvious that the governing board of trustees was willing to adopt a hands-off policy, letting Cornell worry about the building of the campus and White about the educational planning of the University. At its third meeting, the board elected White president of the University. After over three years of prenatal nurturing, Cornell University was born on October 7, 1868.

The opening of Cornell clearly marked a milestone in American higher education. As historian Frederick Rudolph put it in his study of the development of American colleges and universities, ‘‘Cornell brought together in creative combination a number of dynamic ideas under circumstances that turned out to be incredibly productive. There was no way to stop the arrival of the American university. Andrew D. White, its first president, and Ezra Cornell, who gave it his name, turned out to be the developers of the first American university[2] and therefore the agents of

[1] In 1862, the Federal government enacted the Morrill Act to give aid to states to support colleges whose curriculum included agricultural and mechanical instruction. This act helped spawn many state-supported universities throughout the country.

[2] Rudolph held that the University of Michigan was not the first ‘‘American university'' because of the ultimate failure of Tappan and his ideas. Also, Rudolph argued that the seeds for this ‘‘American university'' were widespread and that, soon after the founding of Cornell, they took hold in other institutions like Harvard.

revolutionary curricular reform'' [49, 115–116]. Cornell University was founded to give students a broad and general training ''in distinction to the narrow, old-fashioned college course with a single combination of studies'' [18, 182]. One of the guiding principles behind that emphasis on breadth of training was the concept of utility [53, 60]. In the words of noted historian of American higher education, Laurence R. Veysey, ''During the ten years after 1865, almost every visible change in the pattern of American higher education lay in the direction of concessions to the utilitarian type of demand for reform'' [53, 60]. Cornell, as expressed in its motto, thus sought to be an institution where any person could find instruction in any field, whether that field be history or agriculture. Yet this eclecticism and emphasis on utility needed tempering. According to White, ''there must be a union of the scientific and the aesthetic with the practical in order to produce results worthy of such an enterprise'' [53, 83]. He thus sought to blend the ideal of ''instruction in any field'' with that of creating and maintaining an institution of the first caliber. White set out to find a faculty equal to the task of making this dream of a ''utilitarian'' education a reality.

3. THE FIRST MATHEMATICS DEPARTMENT

The first professor White secured for the new university also happened to be its first mathematician, Evan Williams Evans (1827–1874). A native of Wales, Evans had moved to Pennsylvania at the age of four. Graduating with distinction from Yale in 1851, he taught in various places before becoming professor of natural philosophy and astronomy at Marietta College in Ohio in 1857.[3] He remained at Marietta College until 1864, when he became active in mining engineering. Evans clearly had the kind of background that White wanted for his new Cornell faculty; he had received traditional, ''classical'' schooling, yet he had also become well familiar with ''practical'' applications. After White hired him to assume the leadership of the Cornell mathematics department, Evans spent the year traveling in Europe. While little is known about his year in Europe or his years at the helm of the mathematics department at Cornell, his successor, James Edward Oliver (1829–1895), gives us this glimpse of Evans:

> [he was known as] a man of few words, but of a remarkably sound and independent judgment that carried great weight in the faculty councils, and as an acute and thorough student, a philosophical and original thinker, a firm and loyal friend.... Characteristic of his instruction or policy were: the remarkable power of concentration with which he would follow others' work without using his eyes, his uniform preference for oral above written examinations, and his habit of taking a calculus class over the same ground with two successive authors for the sake of the cross-light. [34, 140]

Evans was joined in the first year by Assistant Professor Ziba H. Potter (1836–?), an A.B. and A.M. from Hobart College in Geneva, New York.[4]

[3] In 1862, Evans wrote a textbook, *Primary Elements of Plane and Solid Geometry*, that he used in his classes at Marietta College.

[4] No specific mention of his mathematical training is available. After his A.M. he completed his M.D. at Geneva Medical College (also in Geneva, New York) and was a surgeon in the Union Army during the Civil War [23, 43].

Three more assistant professors were hired in the second year: William E. Arnold, Henry T. Eddy, and William J. Hamilton. Although little is known about Arnold and Hamilton,[5] Eddy (1844–1921) graduated from Yale in 1867 and from its Sheffield Scientific School in 1868 with the degrees of A.B. and Ph.B., respectively [23, 48]. He went on to receive both the first advanced degree (a civil engineering degree, C.E., in 1870) and the first Ph.D. (in applied mathematics in 1872) granted by Cornell. Eddy earned these degrees on the basis of his own scholarly research, not following any formal graduate program of study at Cornell. He left Cornell in 1873 to go on to a distinguished career in higher education. Given Evan's interest in applied science, Eddy's emphasis on applied mathematics, and the fact that both Arnold and Hamilton had had military training, the faculty of the Cornell mathematics department clearly reflected the utilitarian aims of the university. At the outset, however, its mathematics program was strictly at an undergraduate level. In 1870 and 1871, Evans hired two new faculty members who would begin to orient the department toward work at a graduate level as well. In 1870, Lucien Augustus Wait (1846–1913) joined the staff as an assistant professor, with James Edward Oliver following in the same rank in 1871 [23, 15]. An examination of the changes they brought about becomes most meaningful when compared to an analysis of the mathematics taught at Cornell in the earliest years.

The prerequisites in the first years for entrance into Cornell were minimal by today's standards, but they were consonant with those in place at other American colleges. Only arithmetic and algebra through quadratics were required, and "some students were admitted with only arithmetic" [18, 181]. With such minimal prerequisites, what mathematics did these early Cornell students take? In the freshman year, plane geometry, algebra, and solid geometry were required of all students. During the first part of the sophomore year, trigonometry was required, "including a little on mensuration, surveying, and navigation" [18, 184]. Those in engineering or architecture also took one or two terms of analytic geometry, three terms of calculus, and one term of synthetic geometry [34, 145]. Later in the first decade at Cornell, when the entrance requirements were increased to include plane geometry, freshman mathematics changed by dropping plane geometry and adding trigonometry [34, 145].

Further indication of the similarity between Cornell's mathematics curriculum and that in place at other American colleges of the time is seen in the textbooks used for these courses. Most of the early texts adopted at Cornell were from the popular series authored by Elias Loomis (1811–1889) (except for synthetic geometry, which Evans taught from his notes) [18, 184]. The Loomis books ranged from *Elementary Arithmetic* to *Differential and Integral Calculus* and also included books in natural philosophy, astronomy, and meteorology. In the view of American mathematics historian, Florian Cajori, however, these and other contemporaneous books were "the 'dry-bones' of American mathematical text-books" [18, 180]. Cornell

[5] Arnold had been a major in the U.S. Volunteers [18, 177], and no specific college background is given for him in [23]. Hamilton (1844–1872) graduated from the United States Military Academy in 1868.

mathematics professors starting with James Oliver shared this opinion and went on to write their own texts geared specifically to the Cornell undergraduate.

What especially distinguished mathematics at Cornell from mathematics at most other American colleges in the late 1860s, however, was the concept of "utility" that permeated the university, in general, and the mathematics department, in particular. Under Evans and his assistants, mathematics at Cornell was taught with an emphasis on its application to areas such as mensuration, surveying, engineering, and architecture. Evans, however, headed the department for only six years; he died of consumption on May 22, 1874, at the young age of 47 [23, 15].

4. JAMES EDWARD OLIVER AND EARLY GRADUATE-LEVEL MATHEMATICS

Following Evans's death, the Cornell mathematics department underwent significant changes. From 1873 to 1895, it shifted from a department teaching only "undergraduate" mathematics to one actively engaged in training at the graduate level. The major agent of this change was James Edward Oliver, chair of the department throughout this 22-year period.

Oliver is probably most noted in the general Cornell culture as the "famous absent-minded professor." For example, in a letter to the *Cornell Alumni News* in 1953, Walter F. Willcox (1861–1964), a statistician and former colleague, described this scene involving Oliver:

> He was walking along East Avenue about noon towards his office in White Hall when he stopped to chat with a friend. When the friend started away, Oliver hesitated for a moment and then called out, "Which way was I going when we met?" The friend answered, "Toward your office, Professor Oliver."Having got that steer, he started off, calling out contentedly over his shoulder, "Thank you, that means that I have had my lunch." [58]

However interesting and amusing these stories are, they do little to describe the true nature of James Edward Oliver. He was born in Maine on July 27, 1827, into a family descended from the first settlers in colonial Massachusetts. As a boy he was frail and so spent much of his time indoors involved in books. The state of his health kept him from school until age seven, in fact, but he was nevertheless instructed at home by his mother, herself a teacher. By the time Oliver went to school, he was far advanced in subjects usually not of interest to children his age, chief among them astronomy and literature.

Oliver also developed an ethical sense quite extraordinary for a youth. He was apparently very vocal in his positions against both slavery and the use of tobacco, on one occasion "standing upon the counter of his father's banking-room eloquently expostulating with a group of men addicted to tobacco-smoking or to too much wine" [10, 61]. His ethical convictions were not the mere folly of youth. In later years, "he was on terms of intimacy with the noted anti-slavery leaders of eastern Massachusetts, and was regarded by them as an efficient helper in forming the public sentiment which eventually compelled the removal of this peculiar institution from our country" [10, 61].

At age 17, Oliver entered Harvard as a sophomore. There, his interest in mathematics was stirred by Benjamin Peirce (1809–1880), who thought a great deal of his student's mathematical abilities [34, 141]. Horace Davis, later president of the University of California and Oliver's roommate his last two years at Harvard, described him as "a remarkable man in many respects. He had a strong individuality, amounting almost to eccentricity. He was sturdy and independent in his thought and conscientious in his conviction, yet he was modest, retiring in his demeanor" [10, 62]. As for mathematics, "he devoured [it] with an eager appetite," Davis recounted. "[W]hen, in his senior year, he was given the *Mécanique Céleste* to study he would often become so absorbed as to prolong his work into the small hours of the morning, and I have many times waked up from my first nap to see him still poring over the ponderous volume long after midnight" [10, 63].

Oliver graduated with an A.B. in 1849 and through the encouragement of his mentor, Peirce, took a position with the newly opened Nautical Almanac Office in Cambridge, Massachusetts. This federally funded organization was set up to compile a nautical almanac for the use of commercial as well as naval ships. However, it also became a haven for mathematicians and astronomers [31, 14], and Oliver remained there until just after the office moved to Washington, DC in 1867. In fact, he "did not take kindly to the work necessitated by the publication of the American Ephemeris.... It soon became drudgery to him, and he would rather have devoted his energies to original research in higher algebra" [10, 65]. Only because of the proximity to Harvard and the chance for the intellectual stimulation Peirce and the university offered did he stay with the Almanac Office so long.

In the three years from 1868 to 1871, Oliver's professional life was in flux. In 1871, however, he accepted an offer of an assistant professorship of mathematics at Cornell. His career firmly took root there.

Peirce considerably influenced the development of mathematics at Cornell. Both Oliver (A.B. 1849) and Wait (A.B. 1870) had been Harvard graduates, with Oliver part of the advanced program at Harvard's Lawrence Scientific School[6] "offered at that time by no other institution in the land" [18, 178]. Moreover, the notable William Byerly (1849–1935) took both an A.B. in 1871 and a Ph.D. (one of the first) in 1873 from Harvard, before moving on to a position at Cornell in 1873. Byerly stayed for only three years before returning to teach at Harvard, where he eventually became professor (1881–1913) and served as editor of the *Annals of Mathematics*. It was in the department animated by Oliver, Wait, and Byerly that the mathematics curriculum changed substantially from that of Cornell's earliest years. At its opening in 1868, Cornell offered

> freshmen: Loomis's *Treastise on Algebra* and *Elements of Geometry* plus conic sections; sophomores: Loomis's *Trigonometry* and *Analytical Geometry* plus Church's *Differential Calculus*; juniors: Howison's *Analytical Geometry* and lectures on Modern Higher Geometry plus Church's *Integral Calculus* [24, 135].

[6] Oliver might have been the "one eminent senior" of the Lawrence Scientific School group of 1849 mentioned by Florian Cajori [18, 142], but the catalogs show that he was most certainly enrolled in the Lawrence Scientific School in 1854 and 1855 [18, 178].

Beginning in 1874, however, the curriculum beyond calculus included courses in "differential equations, finite differences, quaternions, imaginaries, mathematical essays, seminary work, etc." for those students pursuing a degree in mathematics [18, 184]. The seminary work was given to those planning on careers in teaching. Following the departure of Byerly and Arnold in 1876, George Jones (1837–1911), a Yale A.B. (1859) and A.M. (1862), was hired as assistant professor, and Lucien Wait was promoted to associate professor to relieve Oliver of some of the administrative burden. These three men, Oliver, Wait, and Jones, formed the core of the mathematics department for the next 18 years. This triumvirate would slowly lead the department toward an active graduate program in mathematics.

As noted above, Cornell offered no graduate-level mathematics initially. By the mid-1870s, however, an "advanced course of study in Pure and Applied Mathematics ha[d] been established for resident graduates, and for such undergraduates as may elect ..." [25, 43]. This marked the beginnings of graduate-level mathematics at Cornell. According to the catalog description,

> Further instruction will be given in algebra and calculus; especially in the theories of imaginaries, elliptic integrals, differential equations, finite differences, and calculus of variations. Also in analytical and anharmonic geometry. Instruction will also be given in analytic and celestial mechanics; and in quaternions, quantics, the theory of probabilities, least squares, insurance, and the theory of numbers [25, 43].

At first, this program attracted few graduate students. In fact, no advanced degrees were awarded in mathematics (with the exception of Eddy's Ph.D. in 1872) until 1885, when Edward Charles Murphy (1859–1934) earned a Masters of Science degree. The next year Hiram John Messenger (1855–1913) took a Ph.D. under Oliver's direction. Murphy went on to study and teach civil engineering, while Messenger became an actuary [19].

Within this same time frame, 1872–1886, The Johns Hopkins University was founded, and James Joseph Sylvester, as chair in mathematics, led the first extensive graduate mathematics program in America. From 1876 to 1884, Hopkins had 16 mathematics fellows and awarded 9 Ph.D.'s [46, 97]. Sylvester's departure for the Savilian Professorship of Geometry at Oxford at the end of 1883, however, left a void to fill in American graduate-level mathematics. Oliver wanted Cornell to take an active role in filling this void. He expressed this sentiment explicitly to the Cornell University president in an 1887 report: "... yet one of our number, whose experience as a student, and as a teacher, enables him to judge,—assures us that, now Professor Sylvester has gone back to England, the opportunities offered here to the average student of the higher pure mathematics are quite as good as those at any other university in the country" [6, 59]. Unfortunately, several factors prevented Cornell from quickly stepping into a leadership role in the emerging American mathematical research community.

First, the backgrounds of the leaders of the Cornell Mathematics Department at this time hindered their overall effectiveness at the graduate level. Neither Oliver nor Wait nor Jones had ever been primarily a research mathematician; none of them had a Ph.D. Although Oliver had the most advanced training of the three, given his work with Peirce at Harvard, he tended to do mathematics without a specific focus and for his own gratification. Arthur S. Hathaway (1855–1934), a former student of Sylvester at Johns Hopkins and a colleague of Oliver at Cornell put it this way: "Professor Oliver is a rare genius, powerful, able, but without the slightest ambition to publish his results. He works in mathematics for the love of it" [18, 179].

Second, and perhaps more importantly, Oliver, Wait, and Jones at Cornell were primarily responsible for an undergraduate mathematics program. For example, in 1880–1881 Oliver taught an average of 18 $\frac{1}{3}$ hours per week, Wait 15 $\frac{2}{3}$ hours per week, and Jones 15 $\frac{1}{3}$ hours per week [1, 12], with most of these hours devoted to the undergraduate mathematics student. Little time remained for graduate level instruction or for publishing original research, even if Oliver, Wait, and Jones had been disposed toward research and publication. The thrust toward the production of original research was unprecedented in America before the founding of Hopkins and was as yet not felt at Cornell. There was a need to publish classroom textbooks, however, and the Cornell faculty did so under joint authorship. Two of their most important books were *A Treatise on Algebra* (1887) and *A Treatise on Trigonometry* (1881). They wrote these books specifically to satisfy the needs of their undergraduate program.

The clash between teaching and research in the decade of the 1880s resulted in a crisis of identity in the mathematics department at Cornell. Oliver led a department still very much suited to teaching undergraduate mathematics, but nevertheless desirous of a graduate program. Reaching that new plateau would undoubtedly mean a struggle with the university's administration. Oliver wanted additional faculty to allow his department time for more than just teaching; he wanted them to have the opportunity to do and to lead in research. Repeatedly in the 1880s, Oliver brought his arguments before the president of Cornell.

In 1883, for example, he wrote in his annual report

> ... I now state that, whenever the income of the University will allow it, there ought to be appointed an additional mathematical professor of a high grade. We can go on satisfactorily and even creditably as we are going, for some time longer, but it should be borne in mind that the science of mathematics has been of late years greatly extended, and that as a consequence at the more important Universities of this and other countries there is a steady tendency toward an increase in the number of mathematical professors. A reason for joining in this movement whenever we shall be able to do so is seen in the fact that in no other department of study is there such an amount of talent scattered about our country and waiting to be developed. Mathematical geniuses are to be found in every part of our land, even among those who have enjoyed few advantages in instruction. To attract and develop this genius and talent should be one of our aims, and this can only be done by drawing into our Faculty more and more men recognized as leaders in various parts of this field of thought. [2, 25]

Oliver was clearly aware that the development of the mathematical talent of American students required increased attention to advanced mathematical education and that more resources would be needed to accomplish this goal at Cornell. He also recognized that these additional faculty needed training to handle more advanced mathematics and required the time to pursue original research. His annual report in 1887 underscored these points:

> We are not unmindful of the fact that by publishing more we could help to strengthen the university, and that we ought to do so if it were possible. Indeed, every one of us five is now preparing work for publication or expect to be doing so this summer, but such work progresses very slowly because the more immediate duties of each day leave us so little of that freshness, without which good theoretical work cannot be done. [6, 58]

He reiterated his position the next year as well, stating that "[o]f course one important means toward this end is the publication of treatises for teaching, and of original work. A little in both lines has been done during the past year, though less than would have been but for the pressure of other University work, and less than we hope to accomplish next year" [7, 75].

5. A VIABLE GRADUATE PROGRAM

During the 1887–1888 academic year, there were 11 mathematics graduate students at Cornell. This represented one-seventh of the graduate work being done in all departments there [7, 74]. Nevertheless, the graduate program in mathematics was still in a fledgling state. Oliver taught the theories of functions and probability in addition to non-Euclidean geometry; George Jones offered advanced work in analytic geometry of two and three dimensions—lines and surfaces of first and second orders—in addition to a course in modern synthetic geometry; and Lucien Wait covered advanced work in calculus—differential calculus. Two relatively new members of the department—Instructors Arthur Hathaway and James McMahon (1856–?)—were also involved in teaching in the advanced program.

Hathaway had done advanced work at Hopkins from 1880 to 1884 and had specialized in the theory of numbers and quaternions. McMahon had earned an A.M. from the University of Dublin, focusing on the "mathematical functions needed in the solution of various physical, statistical and geometrical problems" [19]. At Cornell, Hathaway taught differential equations and a course on quaternions and vector analysis, while McMahon gave advanced work in analytic geometry of two and three dimensions—the general theory of algebraic curves and surfaces—and courses in integral calculus and in the theory of invariants and covariants.

According to Cajori [18, 184–185], books used in several of these courses reflected more or less current trends in Britain and on the Continent at the time. For example, in Oliver's course on the theory of functions, Broit and Bonquet's *Théorie des fonctions elliptiques* and Georges Halphen's *Traité des fonctions elliptiques* were used. In teaching his class on the general theory of algebraic curves and surfaces, McMahon adopted George Salmon's *Treatise on the Analytic Geometry of Three Dimensions* and *Treatise on Higher Plane Curves*, while he used Salmon's *Modern Higher Algebra* in his lectures on invariant theory.

At the end of the 1887–1888 academic year, two students who followed this curriculum earned their Ph.D.'s: Cadwallader Edwards Linthicum wrote "On the Rectification of Certain Curves, and on Certain Series Involved" and Rollin Arthur Harris (1863–1918) explored "The Theory of Images in the Representation of

Functions." Florian Cajori reported that "both of these are very creditable to the writers and to the university," going on to say that the work of Harris "appears to us to fill a gap" [18, 185].

The 1889–1890 academic year marked the beginning of yet another phase in the advancement of the graduate program at Cornell. James Oliver spent the year traveling abroad. He first visited Cambridge to see and hear Arthur Cayley, the inspiration behind much of his own mathematical research. Owing to Cayley's advanced age, however, Oliver's visit there was short. He moved on to Germany to observe both the mathematics taught and the methods of instruction used in higher learning there. In Germany, he mainly visited the university in Göttingen, where he sat in on the courses of Felix Klein (1849–1925). As Oliver described his experiences in Göttingen, "My work here is likely to be of great service to me, including the trains of thought and plans it suggests, no very radically new plans, only as to the spirit, the aims, and the details of my Cornell work" [10, 69]. Klein had made a deep impression on Oliver, and the two men, in fact, became friends. When Klein came to America for the Mathematical Congress associated with the World's Columbian Exposition of 1893, he paid both a personal and a professional visit to Oliver in Ithaca [10, 69]. Klein wanted to see his American friend, but he also wanted a first-hand look at Cornell and its program. Parshall and Rowe sum up the impact of Klein on Oliver this way: "Cornell emerged as a prime sphere of Klein's influence in the United States" [46, 213].

On Oliver's return to Cornell in 1890, several subtle changes began that helped solidify the graduate program over the next 10 years. Almost immediately, Oliver organized a club patterned roughly on the German seminar. The "first regular meeting" of the Cornell Mathematical Club took place at Oliver's home on January 24, 1891, "with the business of organization" on the agenda [22]. In the constitution adopted at that first meeting, "mutual association, and discussion of mathematical questions of interest" defined the club's specific objectives [22]. Today known as the Oliver Club, this organization celebrated its centennial in 1991 and reconfirmed its original commitments: "The Mathematical Club of Cornell University was organized as a forum for discussion of mathematics outside the regular curriculum. The club met in faculty homes on a Friday or Saturday evening for a formal talk followed by discussion of the ideas presented. The Oliver Club is still functioning today, and continues to fulfill the primary goals of the original club" [36]. In founding the Mathematical Club, Oliver intended to get students and faculty involved in mathematics much in the way he saw German students engaged in their seminars.

In the first year, 1890–1891, the club's membership numbered 22. Among the graduate students, the names of Virgil Snyder (1869–1950), John Tanner (1861–1940), and Paul Saurel (1841–1934) stand out on the list [22]. Snyder left Cornell for Göttingen, where he earned a doctorate under Felix Klein; he then returned to a long and successful career back at his *alma mater.* Tanner also left Cornell to pursue his studies in Germany, while Saurel proceeded to Bordeaux. In the 1890s, the Mathematical Club provided an avenue for students and faculty to share their mutual interests in mathematics outside the usual classroom setting. Moreover, it apparently stimulated the students enough to interest several of them in programs of note in Europe.

The decade of the 1890s was, in fact, a time that found many Americans traveling to Europe to study mathematics, and Oliver had much to do with sending Cornell students there to further their mathematics education. In addition to Snyder, Tanner, and Saurel,[7] others, like Annie Louise MacKinnon (1868–1940), first earned her Cornell Ph.D. (1894) and then went on to study in Göttingen. An American Collegiate Alumnae (ACA) European Fellow[8] during the 1894–1895 year, MacKinnon credited Oliver explicitly for her knowledge of this opportunity. In a letter to Felix Klein, she wrote that "[l]ast winter [1893] I heard through Prof. Oliver that you had obtained permission for certain women to attend your lectures" [29, 238].

Not only were American students going off to study in Europe, but European mathematics was being imported more actively into the United States. This was true at Cornell during the 1890s. Capitalizing on Oliver's German connection, the university sent Tanner abroad to study (1894–1896) and to secure a young German professor for Cornell. In May 1895, Tanner persuaded Ernst Ritter (1867–1895) to come to the United States. Ritter had earned his doctorate in 1891 at Göttingen under Felix Klein and had gone on to serve as Privatdozent and assistant to Klein there. Unfortunately, Ritter caught typhoid fever on the trip to America and died before arriving in Ithaca [34, 43]. Wait expressed his sorrow to Klein in a letter dated December 23, 1895:

> I cannot tell you the grief and disappointment that I experienced at the death of Dr. Ritter. As you know, we never saw him as he died in New York. He would have had a great future here for I feel sure that I could have secured advances in salary as often as he should have merited such increase. I have been corresponding with and exchanging cablegrams with Mr. Tanner with regard to Ritter's body. I have nearly all the information to lay before our Board of Trustees. I shall either send it back to Germany or bring it to Ithaca. [38]

This setback did not dissuade Cornell from getting someone with German training into their department. They persuaded Virgil Snyder, who was finishing his doctorate in 1895 and also under Klein, to come back to Cornell as an instructor.

Another untimely death occurred during Tanner's stay in Germany. The leader of the department, James Oliver, took ill and died. The front page of the *Cornell Daily Sun* announced that "[o]n Thursday, March 28th, [1895] Professor James Edward Oliver, whose serious illness has since January kept the whole university world in suspense, breathed out his last life" [21, 1]. Fortunately, Oliver's death did not slow the progress the department had made. Lucien Wait, who had handled most of the administrative work of the department for the previous 18 years, formally took over as department chair and continued to guide Cornell mathematics in the direction defined by Oliver. Wait sketched the department's contours in the same letter to Klein in which he lamented Ritter's death:

[7] Graduate and post-graduate study in Europe during this period was common for Americans (mostly men) in many disciplines.

[8] The ACA European Fellowship was established in 1890 to send promising American women to Europe to pursue post-graduate study [29, 236].

> We have nearly 1800 students this year and there are 167 teachers. We shall get from $100,000 to $150,000 from an estate just settled, which the Trustees are thinking of devoting to pensions for superannuated Professors. I am desirous of bringing a leading German mathematician to America to assist us here at Cornell. I desire to have ONE advanced course of mathematical lectures delivered in the German language so that our students will be able to take hold of work in Germany without so much delay. Mr. Tanner has promised to continue to assist me in this plan. The coming of Ritter was due to a commission that I gave Mr. Tanner when he left for Germany. We shall send two of our graduate students to Europe for an extended course of mathematical study next Summer. . . . I desire to express my grateful appreciation for what you are doing for our students in Göttingen. They not only enjoy your work but they all speak of you with a great deal of affection personally. [38]

As his letter suggests, Wait was committed to the ideals Oliver had embraced; he sought help from Europe, and especially Germany, to strengthen Cornell's graduate program in mathematics.

6. CORNELL MATHEMATICS AT THE END OF THE CENTURY

At the end of the 19th century, the Cornell mathematics department still counted some of the old guard among its faculty. Professor and Chair Lucien Wait celebrated his 30th year in the department, and Professor George Jones his 24th. Two-thirds of the team of Oliver, Wait, and Jones still guided the department as it approached the 20th century. A new department was taking shape, however. In 1894, two new instructors were hired. John Irwin Hutchinson (1866–1935), a student working under the direction of Oskar Bolza (1857–1942) at the University of Chicago, finished his Chicago Ph.D. in 1896, while Daniel Murray (1862–1934) came to Cornell with his Hopkins Ph.D. in hand. As mentioned above, Snyder returned fresh from his studies in Göttingen to take yet another new instructorship in 1895. The following year found Tanner back in Ithaca with a promotion to an assistant professorship, and 1897 brought George A. Miller (1863–1952) to an instructorship following a two-year study tour abroad. These "young lions" solidified the graduate program at Cornell as the 19th century ended and directed it as the 20th century began.

The biggest star in this group of young faculty members was Virgil Snyder. In more than 40 years at Cornell, he published over 80 articles and books, while directing the Ph.D.s of 39 students, 13 of whom were women. He enjoyed national visibility as well, serving as vice-president (1916) and President (1927–1928) of the American Mathematical Society [20].

Relative to research, Snyder also excelled, although his approach was clearly grounded in the 19th century even as others moved beyond those techniques in the early decades of the new century. As his student, Arthur Coble, characterized it, Snyder's early research began

> . . . at a time when geometers were exploring the superstructures of their subject, particularly in space and hyperspace. By adding the radius of a sphere to its coefficients, Lie had defined a sphere by six homogeneous coordinates subject to a non-singular quadratic relation. This situation also occurs with the Plücker line-coordinates so that the parallel between line geometry in three-space and Lie's "Kugelgeometrie" was apparent. Snyder's doctoral dissertation (Göttingen, 1895) was concerned with linear complexes of spheres. Of twenty-one papers he pub-

> lished in the next ten years, twelve were concerned with the metric side of this parallel and dealt with annular, tubular, and developable surfaces, their asymptotic lines, and lines of curvature, or with the development of collateral algebra. [20, 468]

In the middle period of his research, Snyder published a series of articles on surfaces invariant under infinite discontinuous groups of birational transformations, many of which were done in collaboration with his student and colleague, Francis Robert Sharpe (1870–1948). Snyder's culminating work appeared—under the title *Selected Topics in Algebraic Geometry*—in Bulletins 63 (1928) and 96 (1934) of the National Research Council of which he was chair. Coble described these accomplishments this way: ''Of this digest of journal articles up to the date of publication he personally wrote about one quarter of the text and he took on with energy and enthusiasm the entire responsibility for editing and publishing the volume'' [20, 470]. The supplementary volume was ''almost entirely his own work'' [20, 470]. Parshall and Rowe summarized Snyder's overall research status within the American mathematical research community: ''Up until the 1920s, Snyder's prolific output and his talents as a teacher made him, together with Frank Morley of Johns Hopkins, one of the most influential algebraic geometers in the nation. Together with Henry White, in fact, Snyder emerged as a principal heir to Klein's geometric legacy'' [46, 218].

In addition to his extensive body of research in algebraic geometry, Snyder also actively engaged in the education of undergraduates. In the spirit of the Oliver–Wait–Jones department, Snyder coauthored a *Treatise on Differential Calculus* (1898) with McMahon, *Differential and Integral Calculus* (1902) with Hutchinson, and *Plane and Solid Geometry* (1911) with Tanner. All three of these books were used in the lower level courses at Cornell and elsewhere.

Other members of the Cornell mathematics department also contributed to the newly emerging American mathematical scene. John Tanner was active in both the American Association for the Advancement of Science (AAAS) and the American Mathematical Society (AMS), becoming treasurer of the latter in 1907. He also received recognition in *American Men (and Women) of Science* when he earned a star for his research, a distinction reserved for the top people in each field.

John Hutchinson extended the work of his advisor, Bolza, first in his thesis ''On the Reduction of a Hyperelliptic Function to Elliptic Functions by a Transformation of the Second Degree'' and later in continued work in elliptic and hyperelliptic function theory [46, 393–394]. At Cornell, Hutchinson produced Ph.D. students in this and related areas in the early years of the 20th century. During his career, he also published numerous articles and gave many talks at meetings of the AAAS and the AMS, in addition to serving as associate editor of the *Transactions of the American Mathematical Society* and as vice president of the AMS in 1910 [28, 186]. Like Snyder, he earned a star in *American Men (and Women) of Science*.

The oldest member of the new generation of Cornell mathematicians, James McMahon was, like his colleagues, active in the AAAS and the AMS, holding the AAAS posts of secretary (1897), general secretary (1898), and vice-president (1901).

Not as prolific as Snyder, he nevertheless published, presented his work personally at meetings [28, 186], and was starred in *American Men (and Women) of Science*.

Finally, George Miller (1863–1951) worked actively in the theory of groups and directed the studies of two Ph.D. students during his four-year tenure at Cornell. Miller had received his Ph.D from Cumberland University in Tennessee in 1893, and while the quality of that degree may be open to discussion given the state of graduate education in America at the time, Miller augmented his education by traveling to Europe in 1895–1897. He spent the 1895–1896 year at the University of Leipzig, where he may have heard the lectures of Sophus Lie (1842–1899), and the 1896–1897 year at the University of Paris, where Camille Jordan (1838–1922) was lecturing on group theory. Miller brought this mathematics to the faculty and students at Cornell and used it to further his own research agenda. In 1900, in fact, he received the International Prize in Mathematics from the Cracow Academy of Sciences for his work in group theory. This prize carried a cash award of $260 and, in Miller's words, ''would appear to be the first prize in pure mathematics awarded by a foreign academy to an American'' [52]. Miller's work also earned him one of the coveted stars of *American Men (and Women) of Science*.

Miller left Cornell for Stanford in 1901 and eventually moved to the University of Illinois. In all, he published well over 100 articles and books during his career. Miller was also active in the AAAS, serving as its secretary (1907–1912); the AMS, assuming leadership roles in both the San Francisco and Chicago sections; and the Mathematical Association of America, where he held the vice presidency in 1916.

This young and energetic faculty worked hard to maintain and improve the graduate program at Cornell. On paper, at least, the graduate courses they offered looked much like those of the American leader, the University of Chicago. Consider for example, Chicago's listing of advanced courses for the academic year 1898–1899 as published in the *Bulletin of the AMS*:

> The University of Chicago. By Professor Moore: Seminar devoted to research work, especially in groups, algebra, and arithmetic; Transfinite totalities; Elliptic modular functions; Abstract groups; Projective geometry. By Professor Bolza: Elliptic functions; Hyperelliptic functions; Advanced integral calculus. By Associate Professor Maschke: Seminar devoted to research work, especially in linear homogeneous substitution groups; Theory of invariants; Functions of a complex variable; Modern analytic geometry; Higher plane curves. By Assistant Professor Young: Mathematical pedagogy; Theory of equations. By Dr. Boyd: Differential equations and applications. By Dr. Hancock: Calculus of variations; Theory of equations. By Dr. Slaught: Advanced integral calculus; Solid analytics. By Dr. Laves: Analytical mechanics. By Dr. Miller (of Cornell University): Seminar in permutation groups.[9] [16, 490]

Compare this to the listing given for Cornell in that same year:

> Cornell University. By Professor Wait: Advanced analytic geometry; Advanced differential calculus. By Professor Jones: Higher algebra and trigonometry; Probabilities, etc. By Professor McMahon: Higher plane curves; Quaternions; Potential, and spherical harmonics; Mathematical theory of sound. By Professor Tanner: Binary quantics; Theoretical mechanics; German readings. By Dr. Murray: Differential equations; Finite differences; Astronomy. By Dr. Hutchinson:

[9] This was a course he taught in the summer.

> Advanced integral calculus; Elliptic functions; Surface and twisted curves. By Dr. Snyder: Projective geometry; General function theory; Line geometries. By Dr. Miller: Substitution groups; Continuous groups; Theory of numbers. [16, 557]

Were these advanced courses at Cornell ''modern'' by the standards of the day? The course descriptions would make them seem so [26, 135–138]. For example, Miller described the content of his course ''Theory of Groups of a Finite Order'' this way: ''Some of the recent literature on these subjects is examined and the difficulties of problems that await solution are pointed out. The later part of the course is devoted to applications, the Galois theory of equations receiving the most attention'' [26, 136]. His complementary course on the ''Theory of Groups of an Infinite Order'' involved ''a study of the theory of Lie's continuous groups and their application to the theory of differential equations'' [26, 137], making it fairly up-to-date for 1900. Hutchinson underscored his awareness of recent work in the descriptions of both his course on the calculus of variations, where he recommended Adolph Kneser's recent ''work for reference and collateral reading'' [26, 137], and his course on the theory of functions, where he included ''Applications to geometry, particularly to hyperelliptic surfaces and the generalized Kummer surface'' [26, 138]. Similar indications may be found in courses given by Tanner and Snyder as well. At the turn of the 20th century, the Cornell mathematics department was doing a conscientious job of exposing its students to the standard-setting research being done abroad.

7. CONCLUSIONS

The graduate program in the Cornell mathematics department crystallized in the final decade of the 19th century. Its young faculty, animated by a commitment to research, teaching, and service to the broader mathematical community, carried out this transformation. Five of them earned stars in *American Men (and Women) of Science* during their careers; several of them went on to be very active in the AAAS and AMS; a number of them held offices in these associations, culminating with Virgil Snyder's presidency of the AMS in 1927–1928. As trainers of future researchers, they put together a curriculum that was modern by the standards of the day and that incorporated some of the latest contemporary mathematical developments. In the decade from 1900 to 1909, 15 students earned their doctorates in this environment with 16 more following in the years from 1910 to 1919. During the 20-year period between 1900 and 1919, in fact, Cornell ranked sixth among American institutions in mathematics Ph.D. production behind the University of Chicago, The Johns Hopkins University, Harvard, Yale, and Columbia [47, 203].

The Cornell mathematics department also assumed a leadership role on a key issue in the last years of the 19th century: the education of women. Both Ezra Cornell and Andrew White had shown great interest in the education of women. As Rudolph put it, ''[t]he revolutionary reputation of Cornell was greatly advanced by the university's inevitable but delayed adherence to a policy of coeducation in 1872, a delay that had been prompted by the absence of a suitable dormitory'' [49, 124]. On a national level, however, obstacles were more difficult to overcome.

In her work on the history of women in American science, Margaret Rossiter characterized the situation this way:

> When all the attempts by women to gain higher degrees at universities in the United States and Germany over three decades (1870 to 1900) are viewed together, they can be seen as a process of infiltration, a kind of educational 'guerilla warfare' or slow 'war of attrition' against the universities. Under this almost military strategy, individual women sought to test the repressive system on as many fronts (departments and universities) as possible, probing for weak points and using what friends they had to help them evade the rules informally, and, when enough 'exceptional' women had been admitted in this way and had surpassed their fellow students without the imagined disruption, to push for a change in policy, which then could be seen as harmless, 'only fair,' and long overdue, and could be enacted quietly. Thus over several decades a series of women eventually accomplished their objective, but at great human cost. [48, 31]

At Cornell, women found a friendly place in the 1890s. In fact, Cornell's mathematics department granted three of the first six Ph.D.s earned by women in American institutions. Ida Martha Metcalf (1856–1952) earned her doctorate in 1893, followed by Annie Louise MacKinnon (Fitch) in 1894 and Agnes Sime Baxter (Hill) (1870–1917) in 1895. From all indications, they seemed to write their dissertations under James Oliver [29, 235]. As noted above, MacKinnon also pursued her studies in Göttingen under Klein, yet it was characteristic of the times that none of these women realized her full potential with careers in mathematics. As Rossiter argued relative to the women's colleges, ''[s]ex discrimination was so widespread in academic hiring that there was no incentive for the women at these colleges to do any more research. They already held the best jobs open to women, and even with outstanding research accomplishments they were not going to be called to a major graduate school, as the better men at these colleges often were'' [48, 23].

After Metcalf received her Ph.D. she worked for a time as a security analyst in a banking house in New York City. She then won a job in the Comptroller's Office of New York City on the basis of her performance on a civil service examination; she remained in this post until her retirement. It should be noted, however, that ''[i]n view of her own hard struggles to find positions commensurate with her ability, Miss Metcalf, throughout her life had a very cynical view of higher education for women'' [35]. Agnes Baxter Hill's post-graduate experiences were more typical, however. She followed her husband and his career, and spent her time raising their children, but she also battled a serious illness that cut her life short.[10] Of the three Cornell women Ph.D.s, Annie MacKinnon Fitch had a short career in mathematics. After her return to America in 1896 from her post-doctoral studies in Germany, she took a position at Wells College in Aurora, New York. She taught there for five years until her 1901 marriage to Dr. Edward Fitch, Professor of Greek at Hamilton College in Clinton, New York, forced her to leave her position.[11] After

[10] One of Hill's grandchildren, John Roberts, music librarian at the University of California, Berkeley, informed me that his mother, (Hill's daughter) always told him that Hill took the Ph.D. ''for the fun of it.'' She had come to Cornell with her husband A. Ross Hill.

[11] As Rossiter noted, married women were not allowed by most college and universities to hold faculty positions.

her marriage there seems to be no evidence of mathematical activity, although she apparently became somewhat of a community activist.[12]

Cornell granted degrees to two other notable women in the 1890s: Estella Kate Wentz (1866–1938) and Anna Helene Palmie (1863–1946). Wentz earned an M.S. in mathematics from Cornell in 1894, while Palmie took an undergraduate Ph.B. in 1890 and was a graduate fellow in mathematics until 1892. Both women went on to similar careers, taking the sorts of teaching positions that were more the norm for women in that era. Palmie taught at the Women's College of Western Reserve University in Cleveland, Ohio, from 1892 until 1928, while Wentz taught at Emmerich Manual Training High School in Indianapolis, Indiana, from 1895 until 1931 [57, 7–10].

In concluding their study of the emergence of the American mathematical research community, Parshall and Rowe give the following assessment of the forces at work during the final quarter of the 19th century:

> Individuals both at home and abroad, educational institutions both domestic and foreign, general developments in science and its social and cultural status, broader philosophies of education, political rivalries, and the encroachment of modernity in its several guises, these were among the factors that formed the matrix in which research-level mathematics evolved in the United States . . . [46, 453]

The forces they listed certainly acted on Cornell during this period. Andrew White and Ezra Cornell founded Cornell University to give students more freedom in choosing their studies, to provide them with a more utilitarian education. In so doing, they created a model for other American universities to follow. However, this had little immediate effect on the mathematics taught at Cornell. Initially, it was very much the mathematics of the colonial American colleges—algebra, geometry, and some calculus with applications to astronomy, navigation and surveying. There was no significant advanced mathematical training until the German model of research education started to gain favor in the Cornell mathematics department in the late 1880s and early 1890s. Still, the best and brightest students went to Europe for their Ph.D.s or to do post-doctoral study. It was not until the turn of the 20th century, after a nucleus of European-trained faculty were themselves training graduate students, that the Cornell mathematics department became a leader in the American mathematical research community.

The development of the Cornell mathematics department thus paralleled that of the American mathematical research community as a whole. In 1868 Cornell University opened its doors as a place where anyone could study any subject they wanted, but at an undergraduate level. By 1900, Cornell students could study the latest research-level mathematics of Europe. The vision and leadership first of James Oliver and later of Virgil Snyder guided this transformation of the Cornell

[12] According to Betsey Whitman, Fitch "devoted much time and energy to the task of encouraging women to take a public interest, not only in their local community, but also in the affairs of the state and nation" [57, 8].

mathematics department from a strictly undergraduate program to a full-scale, research-oriented department.

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